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TARGETRY AT THE LANL 100 MeV ISOTOPE PRODUCTION FACILITY: LESSONS LEARNED FROM FACILITY COMMISSIONING *

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Abstract

The new Isotope Production Facility (IPF) at Los Alamos National Laboratory has been commissioned during the spring of 2004. Commissioning activities focused on the establishment of a radionuclide database, the review and approval of two specific target stack designs, and four trial runs with subsequent chemical processing and data analyses. This paper highlights some aspects of the facility and the targetry of the two approved target stacks used during the commissioning process.

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Introduction, Materials and Methods

On December 23, 2003, the first 100 MeV proton beam was delivered to the new irradiation facility for the production of radioisotopes at Los Alamos National Laboratory. For the next four months, activities at the new Isotope Production Facility (IPF) [1] focused on commissioning. Pursuant to the demonstration of safe, compliant and reliable operation, particular attention was given to the operation of the beam line, the target station and the targetry [2] at the maximum design parameters.

Two target stack designs were approved for receiving beam during the facility's commissioning process: the first stack, referred to as "Dummy" target stack, consisted of three durable metal targets with niobium in the high energy slot, zinc in the medium energy, and aluminum in the low energy slot. Each target was capable of accepting 250 μA of beam [2,3]. This stack was used to demonstrate safe and reliable operation at 250 μA, the maximum design average beam current. The second target stack, the "Prototype" target stack, consisted of target disks intended for the production of bulk radionuclide quantities: two stainless-steel encapsulated rubidium chloride (RbCl) targets for production of ^{82}Sr occupied the high energy and the medium energy slots, while a niobium encapsulated gallium metal target for production of ^{68}Ge occupied the low energy slot.

Thermal conductivity analyses were performed using computational fluid dynamics (CFD). Basic assumptions for the CFD calculations included a typical ring shaped beam profile as produced by sweeping the Gaussian proton beam in a circle across the target face. Other assumptions were a 250 μA average beam current, 625 μs pulse length at 30 Hz and a 30 GPM bulk cooling water flow rate [3]. One stack of the first type and three of the second type were successfully irradiated during commissioning. During and after bombardments, individual targets were visually inspected for signs of thermal deterioration. These targets were disassembled and transported to the Hot Cell facility for chemical processing.

Figures 1 and 2 depict a schematic view of the IPF construction. The target irradiation chamber is located in the basement of the facility. A retrieval system allows the remote controlled removal of the irradiated item through a well: The target carrier is hauled into a preparation hot cell, where it can be safely handled and packaged for transportation.

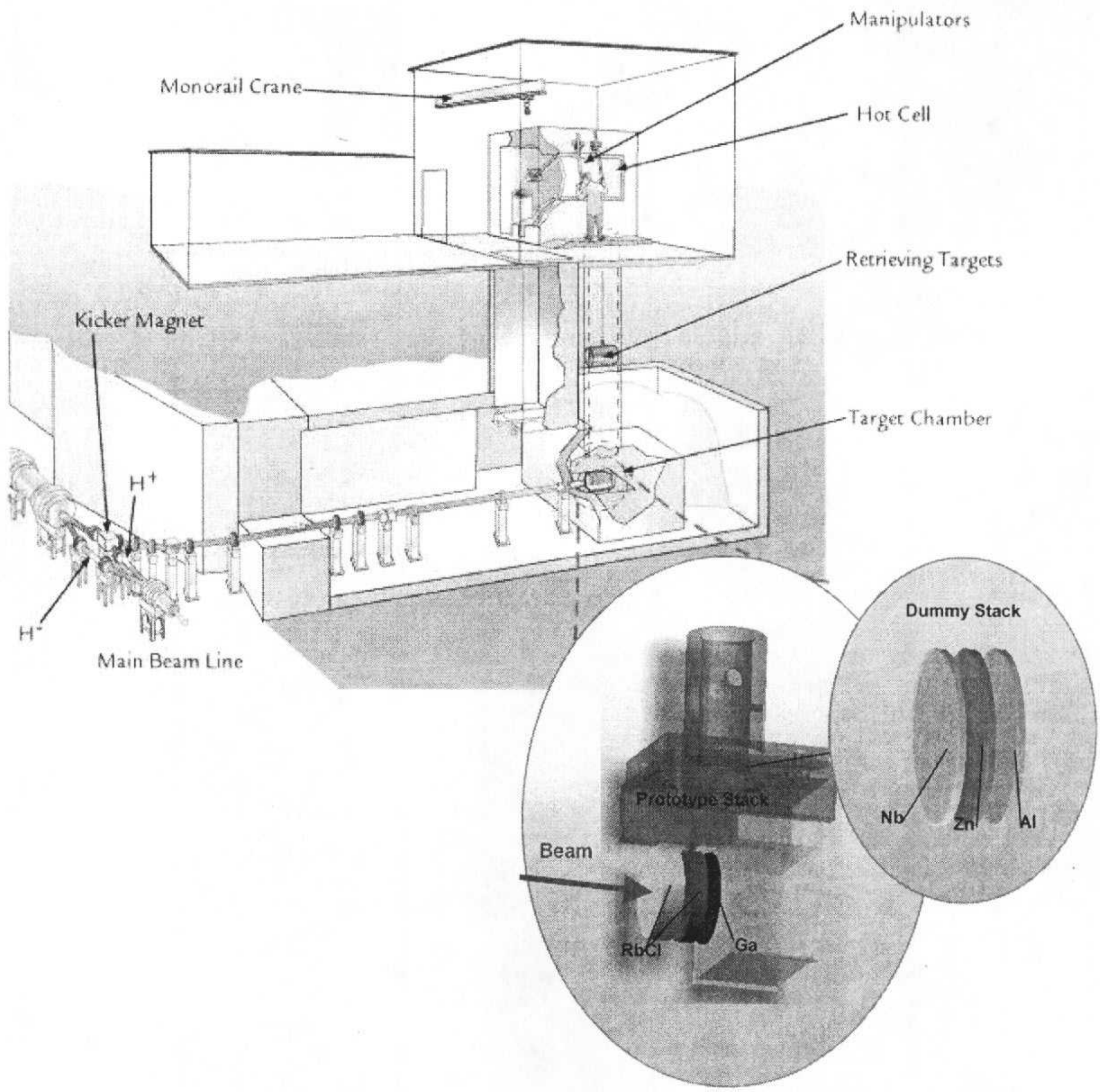

Fig 1. Schematic view of the Isotope Production Facility (IPF) at Los Alamos; the enlarged view shows the two ("Dummy" and "Prototype") target stack designs approved for the commissioning of IPF

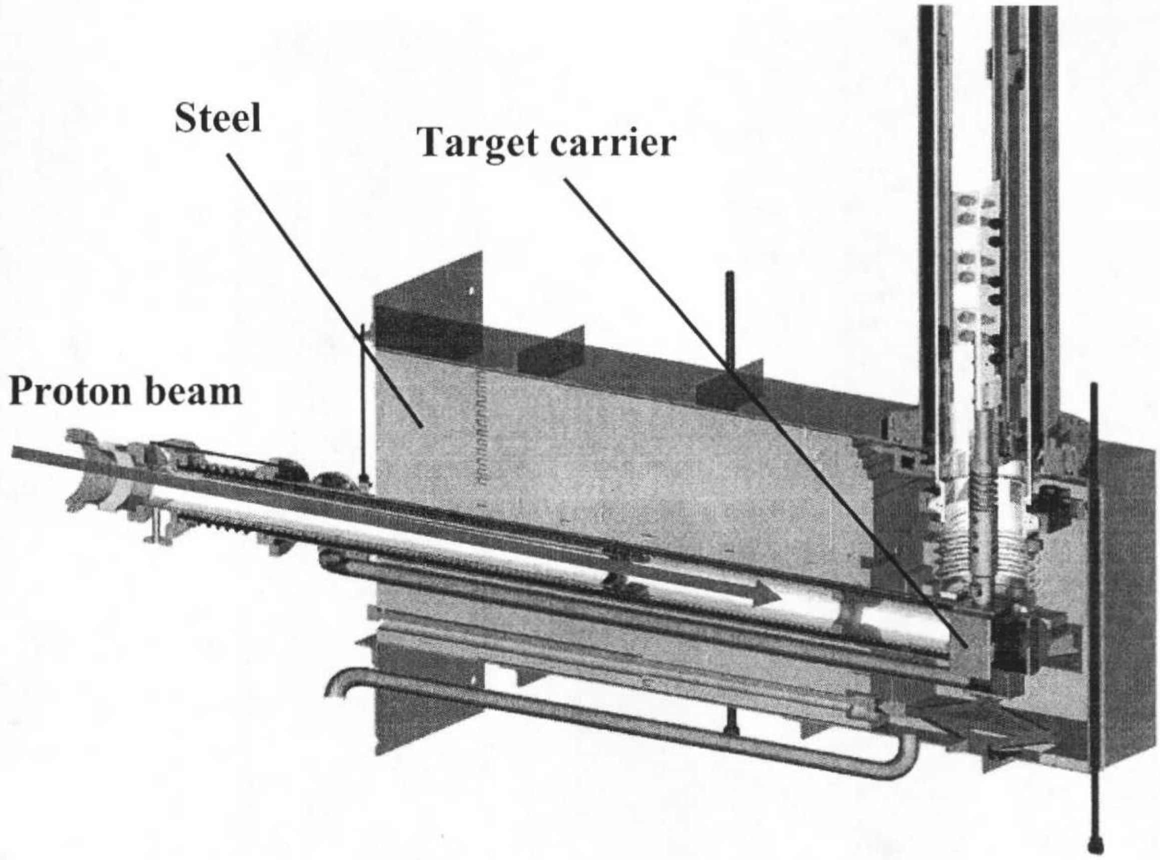

Fig 2. Schematic view of IPF's proton bombardment part: the target carrier is located in a cube-shaped steel box, which, in turn, is surrounded by concrete

Results and Discussion

Table 1 shows the summarized beam parameters for the targets used in this work. Energy values were originally calculated assuming the density of solid RbCl salt. Thermal analysis however, revealed that the salt melts during irradiation. Thus, recalculations assuming the density of liquid RbCl were performed resulting in different beam entrance and exit energies.

Table 2 presents the projected maximum temperatures reached in the two CFD modeled targets of the "Prototype stack". Rubidium chloride was only modeled for the high energy slot. In this case, the maximum temperature exceeds the material boiling point, which is reached at a beam current of 130 μA. Consequently, such targets should be irradiated at beam currents not exceeding 100μA in order to avoid capsule rupture due to pressure build-up.

Table 1. CFD modeled maximum temperatures reached in target materials of the "Prototype" target

Material	Energy slot [MeV]	Beam current [μA]	Max. temp. [oC]	m.p. [oC]	b.p. [oC]
RbCl	[92.4 → 70.4]	150	1623	990	1390
Ga metal	[29.5 → 0]	250	148	30	2204

Table 2. Summary of the target parameters. Energy values were recalculated with respect to corrected RbCl density assumptions

	Maximum Beam Current	Target	Capsule	Energy window (MeV) [recalculated]
Dummy stack	**250 μA**	**Nb**	**NONE**	**93.5 – 71.4**
		Zn	**NONE**	**66.5 – 43.1**
		Al	**NONE**	**35.5 – 7.5**
Prototype Stack	**100 μA**	**RbCl**	**316 SS**	**92.4 – 72.7 [92.4 – 77.7]**
		RbCl	**316 SS**	**65.1 – 45.1 [70.5 – 56.7]**
		Ga	**Nb**	**33.4 – 11.4 [47.4 – 33.4]**

From the results of the CFD analysis, the thermal conductivity-temperature curve of molten RbCl was chosen to be the "Nagasaka" data curve, where

$$k[W(mK)^{-1}](T)=0.249-1.1E\text{-}4\ (T-T_m),\ and\ T_m=990K<T<T_b=1390°C$$

These "Nagasaka" thermal conductivity data are lower than other reported data, and the choice leads to conservative estimates of the maximum beam current allowable for the RbCl salt target.

Table 3. Measured radionuclide yields of the three "Prototype" targets.

Target	Isotope	Half-life (d)	Experimental yield (μCi/μAh)		
			Run#1	Run#2	Run#3
High Energy RbCl	Sr-82	25.5	72	76	58
	Sr-85	64.9	20	18	8
	Rb-83	86.2	-	100	-
	Rb-84	32.8	-	185	-
	Rb-86	18.7	-	110	-
	Br-77	2.375	-	300	-
	Se-75	119.64	-	1.1	-
	As-74	17.77	-	1.2	-
	P-32	14.28	-	85	58
	P-33	25.34	-	-	-
Meduim Energy RbCl	Sr-82	25.5	111	128	140
	Sr-85	64.9	22	28	26
	Rb-83	86.2	-	125	-
	Rb-84	32.8	-	203	-
	Rb-86	18.7	-	115	-
	P-32	14.28	-	26	19
	P-33	25.34	-	-	-
Gallium	Ge-68	270.82	-	8.2	8.5

Only the "Dummy" stack received 250μA of beam for a short time; it was irradiated for 4d and received a total charge amount of 9000 μAh during this period; "Prototype" stack #1, 2 d, 3142 μAh; "Prototype" stack #2, 4 d, 9600 μAh; "Prototype" stack #3, 43 h, 3714 μAh.

The three targets of the "Prototype" stacks (two RbCl disks and one Ga target) were chemically processed according to procedures published earlier [4]. Radioactive assay results are shown in Tab. 3.

Conclusion

Since one niobium encapsulated gallium target developed a blister after the extended irradiation of 4 days, a further evaluation of the gallium targets is required. Beside this gallium target, no other target showed any sign of thermal failure. Considering the uncertainties involved, the production yields obtained for targets irradiated in the same energy slot are consistent for all three "Prototype" stacks.

A careful analysis of the temperature profile in the RbCl targets shows that energy shifts occur in the RbCl and Ga targets. Energy shifts are a result of density variations in the RbCl disk under bombardment. Thickness adjustments of targets in the prototype stack are required to ensure maximum production yields of ^{82}Sr and ^{68}Ge in the design energy windows.

The ^{68}Ge yields obtained are still consistently lower than the predicted [5] yield value, which requires further investigation. After recalculation of the energy windows for the RbCl and Ga targets, the measured ^{82}Sr production yields compare rather well with values predicted on the basis of evaluated experimental excitation function data [5,6].

Acknowledgements

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